ADVANCEMENTS IN DEPLETED URANIUM CATCHBOX DESIGNS FOR BALLISTIC TEST APPLICATIONS

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ABSTRACT

The present article reviews design considerations and structural affectivity of depleted uranium (DU) catchboxes. Environmental considerations have driven technical design advancements required to minimize the environmental impact encountered when decommissioning ballistic test facilities. Furthermore, this paper will review disposal challenges and alternative methods available for DU contaminated soil remediation.

INTRODUCTION

The depleted uranium (DU) Armor Piercing, Fin Stabilized, Discarding Sabot - Tracer (APFSDS-T) 120 mm tank ammunition cartridge is the primary anti-armor choice of U.S. Army's M1A1 Abrams tank.[1] Olin Ordnance has been instrumental in support of the design, development and production requirements of each generation of kinetic energy, DU 120 mm ammunition. As the Systems Manager for the supply of such ammunition, Olin Ordnance has had to provide ballistic test facilities to support the lot acceptance testing of these cartridge components.

This main tactical cartridge is in part comprised of a projectile which uses a high length-to-diameter ratio subcaliber projectile, with a fin-stabilized rod as a DU penetrator element. The combination of high hardness, high strength, and high density makes DU alloys (UY-Ti staballoy) particularly well suited for armor-piercing (solely by kinetic energy) projectiles. Depleted uranium costs and penetrating capability are competitive with tungsten alloys and tungsten carbides. In addition, the high strength of DU suits it for use as a combined penetrator-structural material.

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Figure 1. Typical Design for Kinetic Energy DU Round[2]

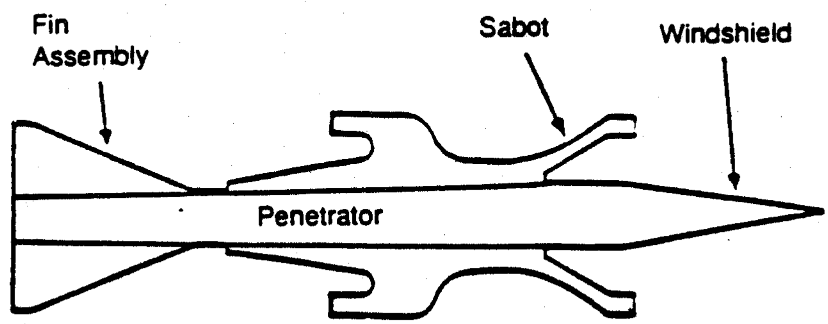

Figure 1. Typical Design for Kinetic Energy DU Round[2]

When fired from a 120 mm smooth bore cannon, the projectiles sabot segments are discarded radially, and the DU penetrator continues toward the target.[3] Figure I shows a typical outline of a 120 mm tank ammunition projectile.

In ballistic test range design, the first priority is human and environmental safety. Once such DU projectiles are weapon fired, it is imperative to stop the DU subcaliber projectile from traveling any further in the open environment than that which is required to obtain the acceptance test data required to qualify the product. Additionally, it is desired to control the impact area to minimize ground surface area contamination of DU. This is accomplished by firing the subcaliber projectiles into a containment area identified as a catchbox.

The U.S. Army Material Command's concern over the safe use of material containing depleted uranium is inherent in its responsibility to promote a safe and healthful work environment for civilian and military personnel. Depleted uranium is frequently misinterpreted, which has resulted either in excessive or deficient safety controls. DU differs from natural uranium primarily in having an appreciably lower uranium - 235 isotopic content. Depleted uranium is the waste product left after natural uranium has gone through the gaseous diffusion process for the removal of the fissionable isotope uranium - 235. DU is useful for non-nuclear applications by virtue of its high density and the structural properties that are attainable. Although potential users may believe that handling depleted uranium presents a complex safety problem, the fact remains that DU is one of the least hazardous of the long life radioisotopes. Sound industrial hygiene practice normally affords adequate protection.[4]

Depleted uranium is classified by the Nuclear Regulatory Commission (NRC) as a low level radioactive material and as such, all scrap must be disposed according to NRC regulations. Historically DU scrap has been disposed by encapsulation and burial in an approved and licensed burial site. However, regulatory trends and general availability of suitable burial sites will limit the amount of material that can be buried in the future and will greatly increase user fees.[5]

CATCHBOX DESIGN CONSIDERATIONS

In 1987, Olin Ordnance constructed its first ballistic test facility for lot acceptance testing of 120 mm tank ammunition at New Mexico Institute of Mining and Technology (NMIMT), Socorro, New Mexico. As part of this facility, the design and construction of a DU catchbox was required to define a containment area for all DU penetrator impacts. In order to establish such a requirement, several parameters were reviewed as identified in Table 1.

Table 1
CATCHBOX DESIGN CONSIDERATIONS
• Previous DU Catchbox Designs • Anticipated Penetration Depths • Volumes of DU Scrap Estimates • Regulatory Requirements • Terrain at Proposed Location/Accessibility • Leaching Mitigation (Soil/Water)

Table 1. CATCHBOX DESIGN CONSIDERATIONS

Previous DU catchbox designs were restricted to open-air environment application. The New Mexico catchbox was designed for identical applications, however no considerations were given to future technological advancements in penetrator terminal effects against armor. This directly effects depth of penetration into soil.

Volumes of DU scrap were estimated on a basis of forecasted Army out-year acquisition requirements as it was known at that time. Consideration was given to potential volume swings for surges and elimination of such ammunition requirements.

A 120 mm ICE cartridge contains over 10 pounds of DU. Estimations of 5,000 rounds to be fired in 5 years drove the catchbox size configuration.

Regulatory requirements of the NRC and State of New Mexico Environmental Improvement Division Radioactive Materials License Number NM-INT-DU-05, dated November 24, 1986, were also considered. Background radiation surveys, ground water purity levels, total DU radioactive material levels and frequency of clean up were all incorporated into the design considerations.

The terrain conditions required significant modifications to enable compliance with ballistic test parameters. The impact point was required to be approximately 50 feet lower than the available terrain level at that time. The impact point was embedded into the base of a mountain, which required removal of several feet of superficial deposits of gravel, sand and soil, as well as the rock beneath known as bedrock.[6] Furthermore, accessibility to the DU Catchbox and surrounding area was required in order to enable periodic and routine radiological surveys to monitor radiation levels in the immediate surrounding area.

Finally, considerations were given to minimizing soil contamination and DU leaking into soil as well as ground water or runoff water contamination. A concrete base with wing walls were designed as the base structure of the catchbox. This was sloped forward to direct drainage of rainwater. The base structure was fabricated directly on top of the bedrock strata thereby preventing direct access to ground water.

Based upon the above considerations and factors, the design and construction parameters as detailed in Table 2 and Figure 2 were developed.

Table 2

OLIN'S CATCHBOX DESIGN PARAMETERS

Catchbox Floor	1 foot thick reinforced concrete; 5 sections at 30' x 20' each.
Stem Walls (sides)	8" thick x 4' high x 100' deep.
Wall Frames	Steel 8" I-Beams.
Walls (sides)	1/8 inch steel sheeting welded to Frames
Front Wall	1/2 inch steel plate (30' x 8')
Baffle/Witness Wall	1/8 inch steel sheeting located at 80' depth as witness sheet (Note 1).
Fill Material	Clay/Sand mixture fill.

Note 1: "Witness Wall" was established at 80 feet depth to minimize clean-up costs when decomissioning. If the witness plate showed no evidence of perforation, the last 20 feet depth of catchbox would be deemed uncontaminated.

Table 2. OLIN'S CATCHBOX DESIGN PARAMETERS

Figure 2. Olin's Catchbox Design

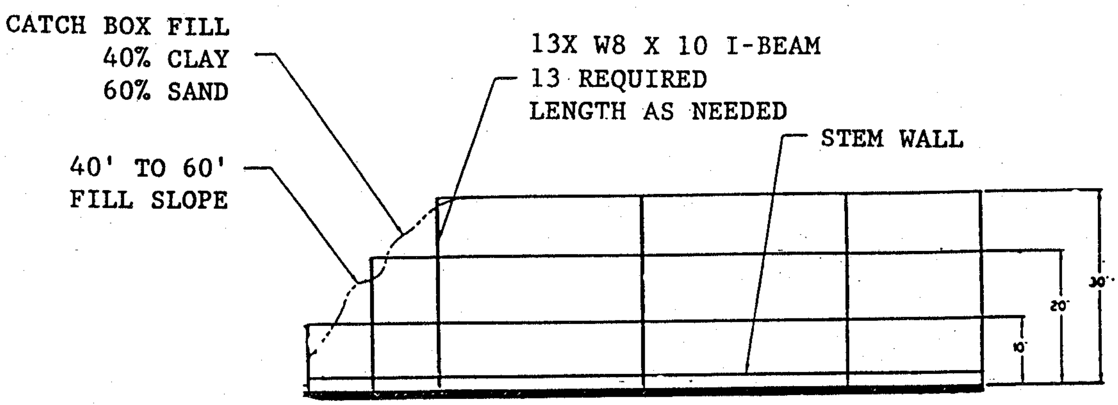

Figure 2. Olin's Catchbox Design

ENVIRONMENTAL ASSESSMENT

Subsequent to the design and construction of the Olin Ordnance DU catchbox in New Mexico, an environmental assessment was performed by the U.S. Army in 1988 on the life cycle of a cartridge containing a DU subcaliber projectile. Key findings of the report include:

a) There is a limited potential for contamination of the air by resuspension from the soil at accuracy test ranges. While there is no projectile breakup on impact with soft targets, fragmentation into smaller pieces is possible if projectiles hit trees, rocks, or other spent ammunition on the test range. There is some minor concern that small, fragmented, or corroded particles of DU might be resuspended with the top few millimeters of soil. Several studies indicated that the major concentrations of contamination was in the upper 5 cm of soil and within about 100 to 200 meters of the-target. No appreciable migration into the soil was observed. However, large DU fragments as well as fine particles may corrode and migrate into the soil. Corrosion rates are determined by the - time of exposure, temperature, moisture, surface area exposed, and other site specific factors. While weathering is faster in humid environments, quantification of specific weathering rates for DU penetrator alloys has not been determined. For resuspension of DU, the greatest potential problem is in arid regions where dust storms are prevalent.[7]

b) During accuracy testing, there is a potential for release of material which could affect both surface and groundwater quality. DU could enter the aquatic pathways from accuracy test sites via runoff, leaching, and airborne deposition. Studies of the dissolution rate of DU dust from a test range indicate that DU is relatively insoluble in both sea water and fresh water, having a half-time for dissolution of 4.8 and 6.8 years respectively. Degradation of DU penetrators by reaction with oxygen results primarily in uranium oxides, UO^2 and U_3O_8, which are relatively insoluble in both media.[8]

c) The greatest potential for contamination of soil occurs during open-air accuracy testing. On those few occasions during testing, when a projectile impacts a rock or other hard surface downrange, adverse effects to the terrestrial environment may arise from the dispersion of DU particles and fragments. Radiation level measurements at an accuracy test range in use for five years showed that surface contamination was comparable to background reference levels except in isolated hot spots where penetrators were found. The average uranium concentration in the soil within the test range was found to be similar to levels obtained at an uncontaminated reference area at the site. Studies of depleted uranium movement in soils at test ranges show that there is very little vertical movement of material from the deposition area. Consequently, the potentially impacted area is limited to the soil in the upper layers of the range itself.[9]

CATCHBOX DECOMMISSIONING FINDINGS

In 1993, Olin Ordnance decided to construct a second generation ballistic test facility in Camden, Arkansas. This facility operates to the same mission as that in New Mexico. To facilitate the decommissioning effort in New Mexico, an initial site characterization for radioactivity around the catchbox was undertaken in 1993 and followed up with a final, confirmatory characterization in January 1994. This analysis was accomplished as both an evaluation of the sites remediation requirements as well as establishment of potential design considerations not incorporated in the original catchbox design.

The site characterization divided the range into the areas of Catchbox, Splash and Throwout Zone, Approach Area and High Explosive (HE) Range. Figure 3 defines the general impact area.

Results of the characterization identified contamination within the catchbox and outside the catchbox in the immediate surrounding area only. Approximately 3,100 DU rounds have been fired into the catchbox over a 7 year period. Table 3 details the volume estimates of contaminated soils in each of the range areas.[10]

Table 3			
DU CONTAMINATION ESTIMATES			
LOCATION	CONTAMINATION	EST. VOLUME	EST. BASIS
Catchbox	Heavy Throughout	63,000 ft^3	Design capacity and current fill
Splash Zone	Surficial	350 ft^3	350' radius from catchbox
Near-Miss Strikes	Sporadic, low in banks	270 ft^3	Site personnel experience
Approach Area	Within 2" of surface	11,700 ft^3	Physical dimensions
HE Range	Surficial & Subsurface	7,500 ft^3	Site personnel experience

TOTAL ESTIMATE: 82,820 FT^3

Table 3. DU CONTAMINATION ESTIMATES

Figure 3. Site Drawing

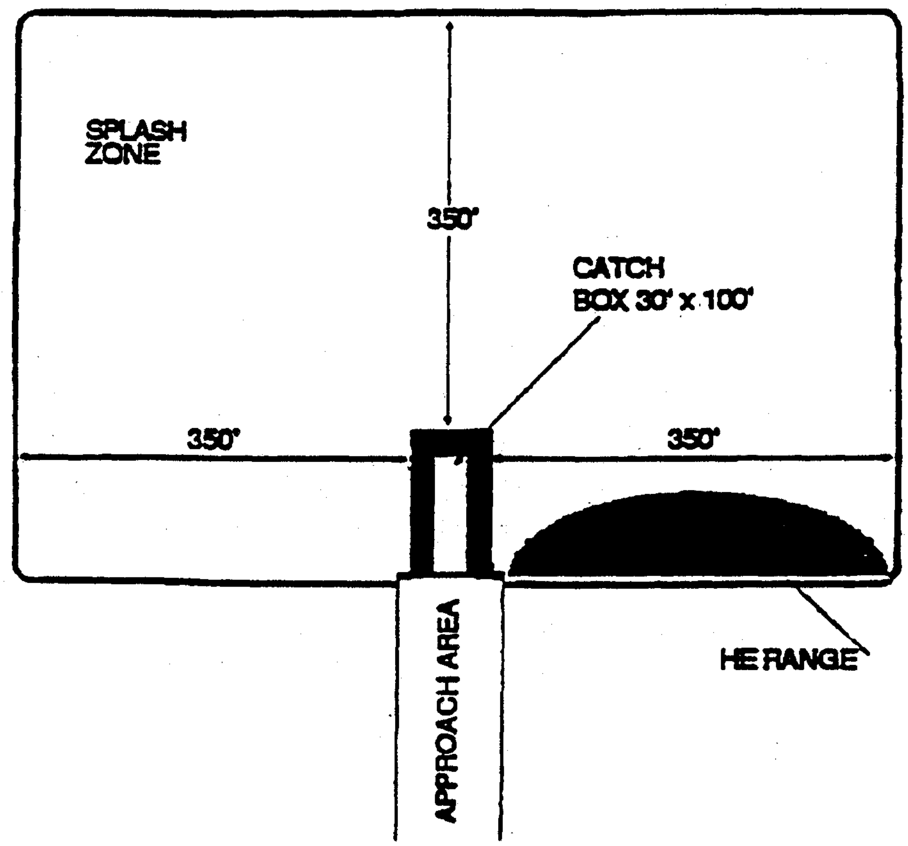

Figure 3. Site Drawing

ADVANCEMENTS IN CATCHBOX DESIGNS

In 1993, Olin Ordnance designed and constructed a second generation ballistic test range for the lot acceptance testing of 120 mm tank ammunition in Camden, Arkansas. As part of this facility, a DU catchbox was constructed. Different challenges were addressed and overcome as well as incorporation of environmental considerations identified in follow~nyears from the original design. Based on the findings and past operations of the Olin ballistic test range in New Mexico, it became evident that design improvements in DU catchbox structures would minimize future clean up and range decomissioning efforts and cost. Containment of DU particulates and fragments are essential design characteristics which must be addressed in the planning stages of any ballistic test facility which will evaluate DU type ammunition. Of key importance was the requirement to mitigate environmental impact of water, surrounding soil and air resuspension. Furthermore, Arkansas has significantly more rainfall than New Mexico, therefore, rainfall considerations had to be addressed. Additionally, the terrain was considerably different than that of the New Mexico site. The Arkansas site was contained in a relatively flat wooded terrain and the impact point required the fabrication of an impact hill. Within this impact hill, the catchbox was centrally located. The earth used to build the impact hill was obtained from directly in front of the impact hill. However, provisions were required to prevent water pooling from rain runoff. This entailed fabricating controlled drainage which prevented DU water contamination and still allowed runoff and pool drainage. Figure 4 provides an overview of the Arkansas Test Facility. To facilitate those requirements, structural changes were made to the original design.

To mitigate the environmental concerns previously identified, a rubber liner was placed between the catchbox floor and the compacted earth subgrade. The front side walls which were fabricated out of 1/8" steel plating, as in the original design enclosed the complete side surface area, thereby eliminating any side splashing of DU fragmentation. The catchbox top was enclosed with steel rcofing over the first 40 feet of depth. The remaining 60 feet was buried into the impact hill itself. This eliminated any potential for DU fragmentation splash out over the top of the catchbox. The back walls were fabricated from concrete block, allowing for earth fill of the catchbox to coincide with the impact hill construction. To contain rain water runoff from the rain impacting the front face opening, a Weir system (Figure 5) would be inserted directly in front of the catchbox. The Weir system is a series of baffles which allows for settling of heavy DU particulates in the base on each baffle prior to releasing the water runoff to drainage. Secondary, Weir systems would be located within the drainage trench to catch any potential contamination during drainage of the pooling area.

The Arkansas Catchbox was further modified to add ten feet to the width of containment area. This gave a total impact surface area of 40' x 40'. This increase in size compensates for the near-miss strikes incurred at the New Mexico site. Figure 6 provides the details of the Arkansas DU catchbox.

DISPOSAL CHALLENGES

Changes to radioactive waste disposal management practices have occurred as a result of the federal Low Level Waste Policy Amendments Act of 1985. This law established the requirement of regional solutions to regionally generated low level radioactive wastes. The formation of multi-state compacts to address the management of these wastes began and this process eventually lead to the development of regional disposal sites. Ramifications of this law remain uncertain. At a minimum, facilities will face large increases in radioactive waste disposal costs in the future and available space for burial will be limited.[11]

As the various multi-state compacts were developed, several varying restrictions have been evidenced by Olin. New Mexico is a member of the Rocky Mountain Compact. There are no approved disposal sites within this Compact. Therefore, DU disposal must occur outside this Compact region. This organization must approve all shipments of low level radioactive waste (LLRW) which is to be shipped outside of the Rocky Mountain Compact states. To dispose of the Olin DU waste, transport to the Northwest Interstate Compact is required. The original license under which Olin was provided testing services identified the Beafty, Nevada disposal site for future LLRW disposal. However, in December 1992, the Beatty disposal site closed down. The only available approved disposal sites are Envirocare in Clive, Utah or U.S. Ecology in Richland, Washington. Both sites are within the Northwest Interstate Compact. Restrictions exist between this compact and Washington state not to exceed 6,000 cubic feet of waste material per year from the Rocky Mountain Compact. Exceptions and negotiations are an everyday fact of waste disposal.

When planning ballistic test facilities which will support DU testing, clean-up and ultimate decommissioning are critical points in the overall operation. Regulations from state to state differ as do those between multi-state compacts.

FIGURE 4. RANGE OVERVIEW - ARKANSAS

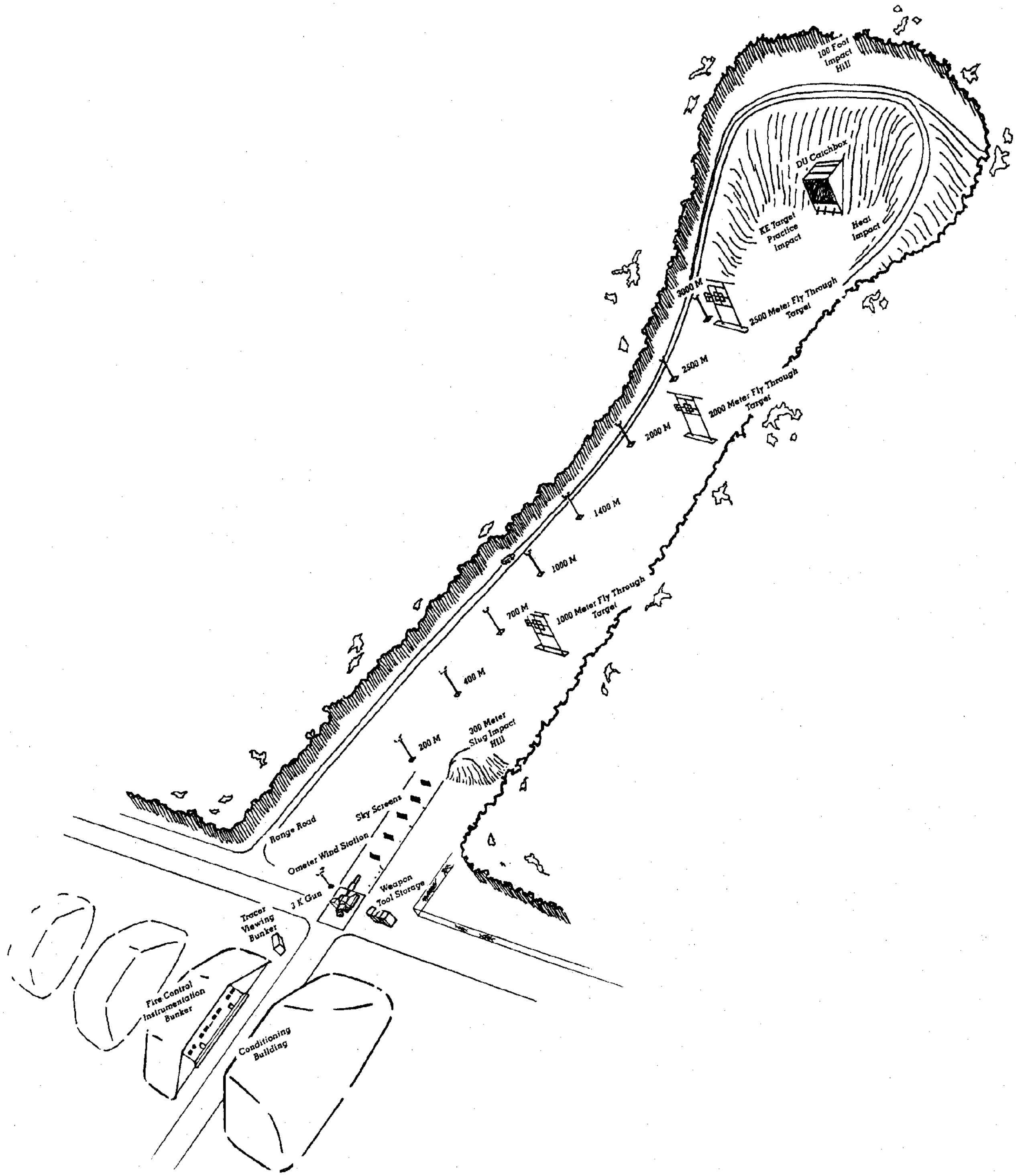

Figure 4. Range Overview - Arkansas

FIGURE 5. WEIR SYSTEM

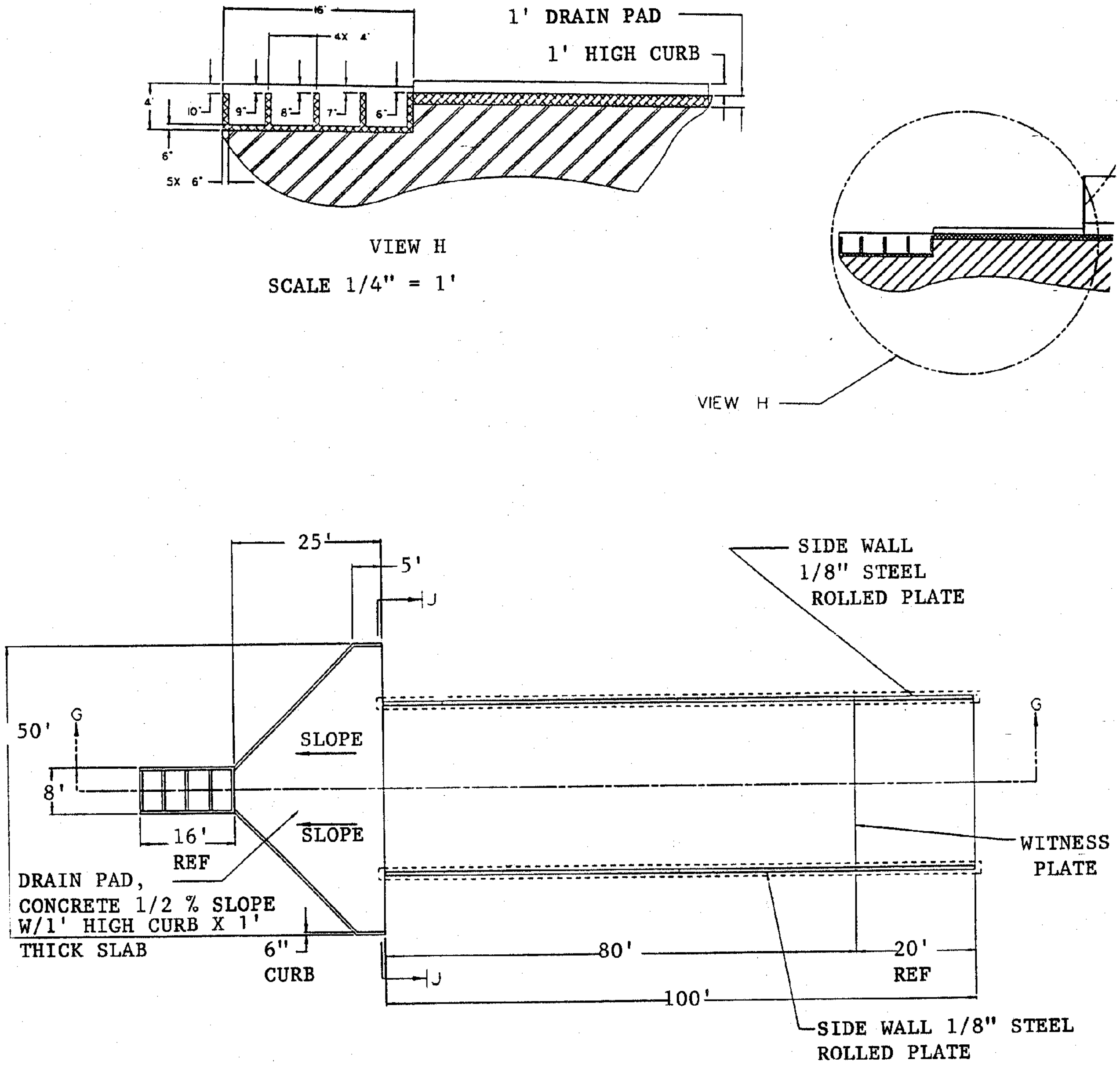

Figure 5. Weir System

FIGURE 6. ARKANSAS DU CATCHBOX

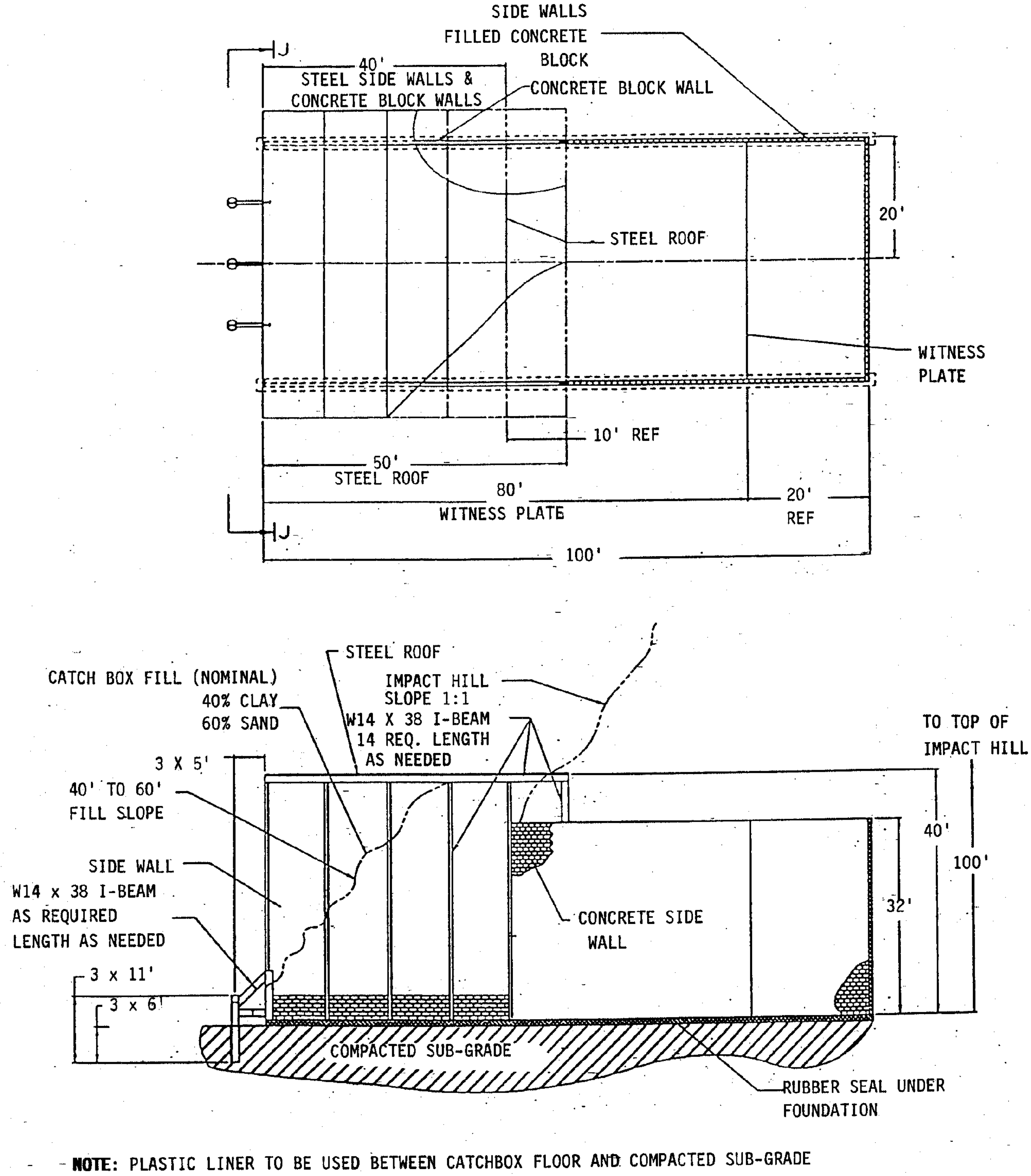

Figure 6. Arkansas DU Catchbox

When construction began in Arkansas on the Olin test range, the Central Interstate Low Level Radioactive Waste Compact (CIC) had not yet identified a disposal site for LLRW. Their preferred site was to be in Nebraska, however complications in licensing the site during July 1993 delayed its facilitation. Arkansas and the CIC took action to regain access to the Barnwell, South Carolina facility. This grant is temporary and resolution to the Nebraska site is imperative. Due to these issues and others, Olin has elected not to use the Arkansas facility for testing DU projectiles until the disposal and regulatory problems are solved.

Disposal challenges are very real and more challenging than the resolution of environmental concerns. Even after the technical issues are resolved, the operational design will be controlled by the regulatory requirements of each state and multi-state compact.

ALTERNATE REMEDIATION METhODS

The typical remediation effort utilizes relatively low level technologies associated with excavating, packaging, and shipping to an approved disposal site. Several management and operational criteria must be addressed in order to assure compliance with applicable laws and regulations. A typical cleanup effort contains the elements of those shown in Table 4.

This approach, though less risky, does not provide for reduction in volume techniques which would ultimately reduce the quantity of LLRW required to be disposed and its associated disposal cost.

Some volume reduction techniques being developed or in use today are sifting, soil scrubbing, soil washing and bioremediation[12]. As volume reduction techniques are evaluated, technical risks and cost risks both rise. However, ultimately the development of such techniques are required as disposal sites become fewer and burial costs become higher.

SUMMARY

The present review has identified the environmental considerations associated with DU testing and catchbox designs. Furthermore, although technologies exist to mitigate environmental impact when firing DU projectiles into catchboxes and technologies exist for final clean-up and decommissioning, regulatory and disposal concerns are very evident and must still be resolved prior to proceeding with any new ballistic testing of DU ammunition.

ACKNOWLEDGEMENTS

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Table 4. Range Clearance/Remediation

ORGANIZATION OF FUNCTIONAL RESPONSIBILITIES

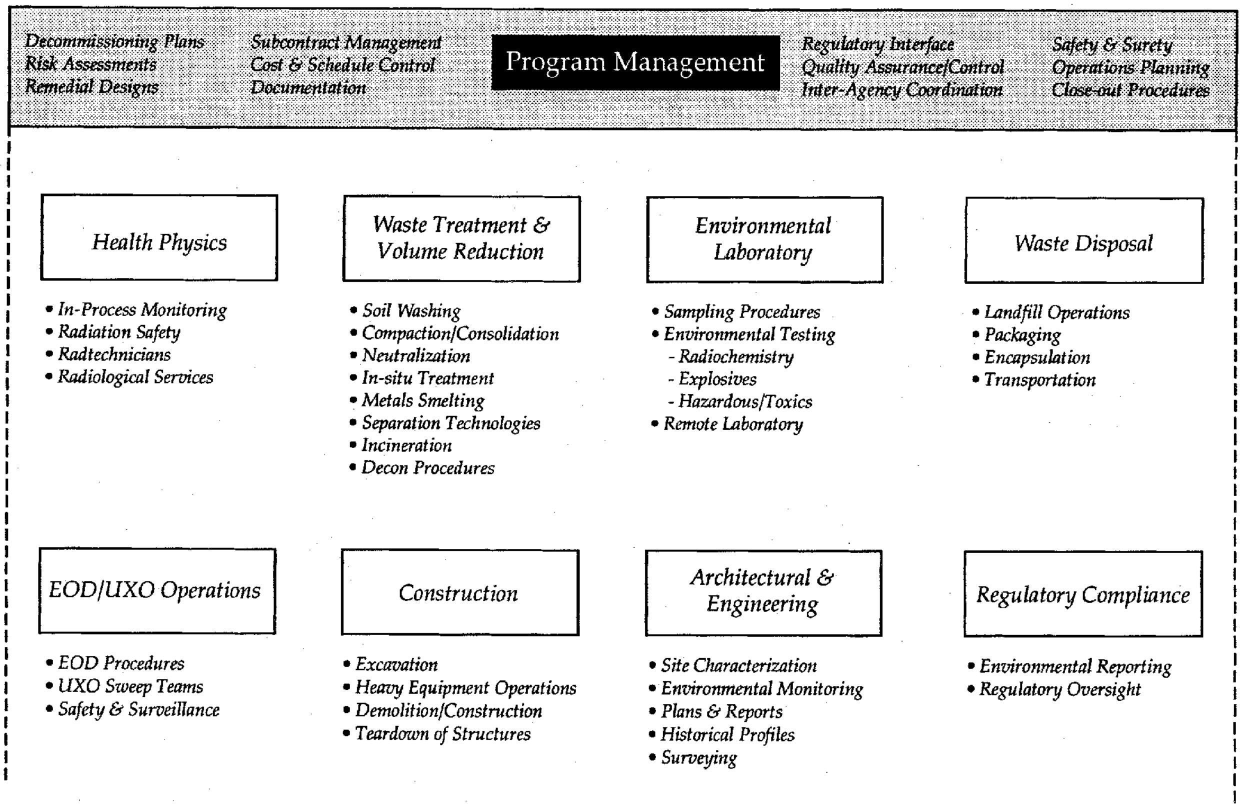

Table 4. Range Clearance/Remediation

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